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DRYLAND SALINE SEEP CONTROL

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Introduction

Dryland saline seepage is a major soil problem in Alberta. Approximately three million acres (1.2 million hectares) of dryland are affected by salinity. The problem is caused by the excess water in recharge areas percolating deeply beyond the root zone. As a result, the water table rises especially in lower lying discharge areas, where wick action drives the saline water to the surface, and salts accumulate because of evaporation. The key to controlling dryland saline seepage is the appropriate management of water: either encouraging maximum use of water by plants in the recharge area or by draining subsurface water in the discharge area.

The purpose of this publication is to explain the nature and mechanism of the problem and the controls available. The following topics will be addressed:

- nature of the problem
- formation of dryland saline seeps
- sources of salts and excess water
- dryland salinity investigation service
- controls: vegetative and mechanical.

Nature of the problem

Saline seepage found in dryland conditions is defined as the presence of saline water on an intermittent or continuous basis at or near the soil surface downslope from recharge areas. It reduces or eliminates crop growth in the affected area because of the increased concentration of soluble salts in the root zone. Saline seeps can be differentiated from other saline soil conditions by their recent origin, saturated root zone and shallow water table (Brown et al., 1983.)

Saline seeps are characterized by a high water table, an accumulation of salt, the presence of salt tolerant vegetation, and in some cases by hydrostatic pressure. The high water table makes the site wet and inaccessible to equipment. When groundwater is under pressure springs and soapholes may result.

Salts accumulate throughout the upper portion of the soil profile, and especially on the surface. The salt content of a soil can be estimated from an electrical conductivity measurement expressed in deci-siemens/metre (dS/m) as made on a saturated soil paste extract (Table 1). The predominant salts in our soils are sodium and magnesium sulfates. The sodium adsorption ratio (SAR) is used as a measure of the effect of sodium in the soil. Soils high in sodium (SAR >13) are said to be "sodic", and often exhibit poor tilth and low permeability. Most of our saline soils are sodic.

Table 1. **Classification of Severity of Soil Salinity (Expert Committee Soil Survey)**

	Class (dS/m)				
Depth (cm)	**Non**	**Weak**	**Moderate**	**Strong**	**Very Strong**
0 - 60	<2	2 - 4	4 - 8	8 - 16	>16
60 - 120	<4	4 - 8	8 - 16	16 - 24	>24

The high concentration of salt prevents the uptake by plant roots of water and essential nutrients. Some specific salts are toxic to the plants. However, some native plants are tolerant to salinity.

Salt tolerant vegetation is a useful indicator of salinity. Red samphire (*Salicornia rubra*) and sea blite (*Suaeda depressa*) are very salt tolerant. Wild barley (*Hordeum jubatum*) is fairly salt tolerant and water loving. Kochia (*Kochia scoparia*) tolerates only lower levels of salt (< 8 dS/m).

Potential saline seeps can be identified many years before they appear in their full severity. The sequential characteristics are:

- flush in crop growth, combined with excellent yields
- increasing wetness, causing inaccessibility
- lush growth of Kochia in the fall amidst a mature crop.

These initial stages in the surface development of a saline seep are soon followed by more damaging and obvious ones during the maturing of the saline seep, as follows:

- decreasing crop yields
- dying crops
- invasion by salt tolerant weeds which appear in concentric rings, with the most salt tolerant weeds appearing in the centre of the seep
- salt accumulation on the surface.

The size and severity of the affected area at each stage increases in all directions, but primarily upslope.

Associated with the soil salinity problem is the salinization of shallow groundwater and surface water supplies. A few cattle die in late summer each year because evaporation concentrates the already salinized surface water supplies (i.e., ponds, sloughs, dugouts, etc.) to a toxic level.

Extent of the problem

Approximately 3 million acres (1.2 million hectares) of dryland in Alberta are affected by saline seepage (Figure 1), with an average crop yield reduction of

about 25 per cent. Soil salinity ranges from severe to mild. In a saline seep, the salt concentration is highest in the centre of the seep, and decreases towards the edges, as is indicated by the concentric rings of vegetation of variable salt tolerance. In Alberta, areas around Warner, Vulcan, Lethbridge, Provost, Oyen, Mundare and Vegreville are most affected. The problem is also present in other provinces and states of the northwestern Great Plains region. The extent and severity of the dryland saline seep problem increases at an average of approximately 5 per cent per year, but faster following a few wet years.

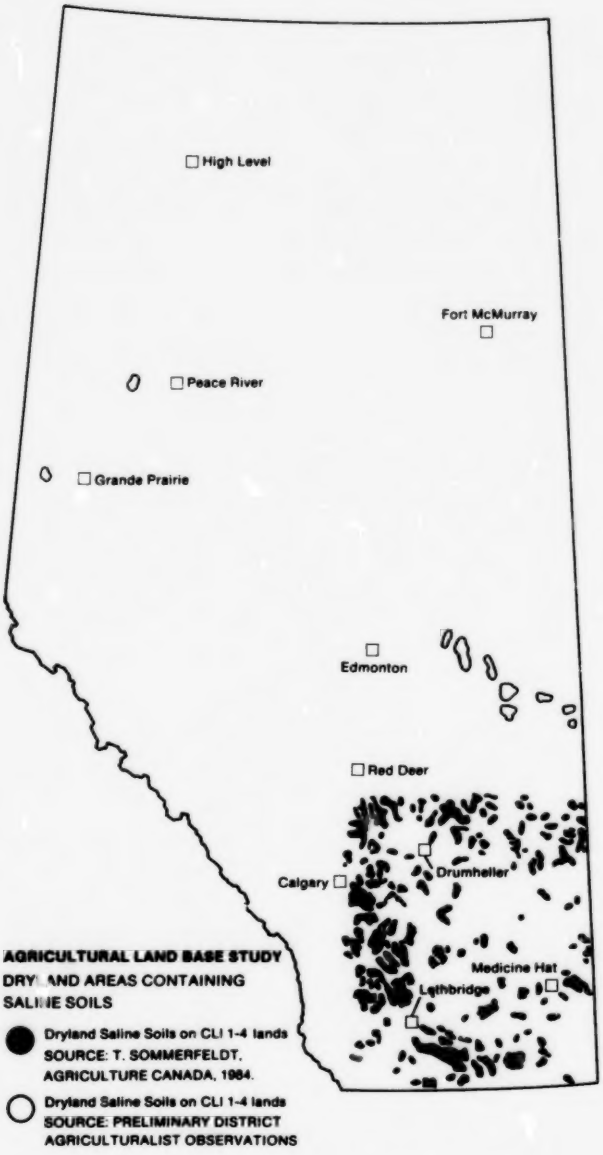

Figure 1. Areas in Alberta affected by dryland saline seepage.

Mechanism of dryland saline seepage

Long before the first agricultural settlement was established, large areas of Alberta contained saline seeps. Those saline seeps formed under natural conditions. However, during the last few decades the extent and degree of salinity have shown a rapid increase. This acceleration results from man's interference, and is largely the result of agricultural practices.

Recharge-discharge mechanism

The development of saline seeps involves two areas in the field: the recharge and discharge areas. In the recharge area, water in excess of the water-holding capacity of the soil in the root zone percolates beyond the zone, reaches the groundwater and increases the flow to the discharge area (Figure 2). The groundwater flow is mainly lateral and downslope, and occurs most often over a shallow, less permeable layer. In Alberta, most of the groundwater flow systems are local in nature, meaning the recharge and discharge areas are within a distance of one kilometre. The groundwater travelling to the discharge area dissolves and picks up salt from the soil. In the discharge area, the influx of groundwater causes the water table to rise until it is within the capillary zone. In the capillary zone, cohesive and adhesive forces in the micropores pull the water to the surface. At the surface, the saline water evaporates, leaving the salts behind to accumulate.

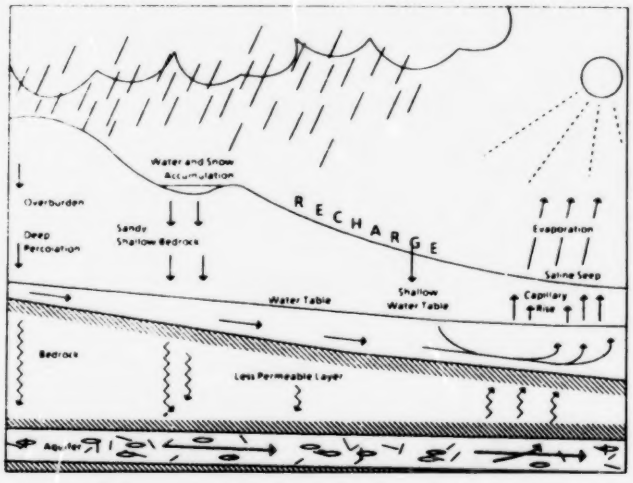

Figure 2. A typical recharge-discharge mechanism and its dominant recharge areas.

All of the upslope area outside the discharge area is considered a recharge area. The degree that it recharges varies from site to site and over time. Dominant recharge areas are those portions of a field that contribute more to deep percolation than any other part of the field. Dominant recharge areas are characterized by water and snow accumulation on the surface, for example: depressions, drainage courses, snowfences, borrow pits and shelterbelts, and by soils with low potential for additional moisture storage, for example those with coarse textures, shallow bedrock (less than 2m) and shallow water tables (Figure 2).

Preventive controls are concentrated on the dominant recharge areas, because then maximum control can be obtained with a minimum amount of expense, time and change in cultural practices on the whole farm.

Types of saline seeps

The different types of dryland saline seeps are characterized by the mechanism used in their formation. In Alberta six different types are recognized:

1. Slope-change saline seep (Brown et al., 1983) - Figure 2 depicts the slope-change seep mechanism. The groundwater flows laterally downslope on top of a less permeable layer. At the toe of the hill the slope gradient decreases, causing the water movement to slow down and the water table to rise, resulting in a saline seep. The expansion of the saline seep is mainly downslope, and somewhat upslope. These saline seeps are common in all salt affected areas of Alberta.

2. Texture-change saline seep (T.S. Sommerfeldt) - These saline seeps result from a blockage of a shallow, lateral groundwater flow by less permeable, finer textured overburden (Figure 3). The less permeable surficial material blocks the movement of water and causes the water table to rise. These saline seeps often occur on the side of a hill.

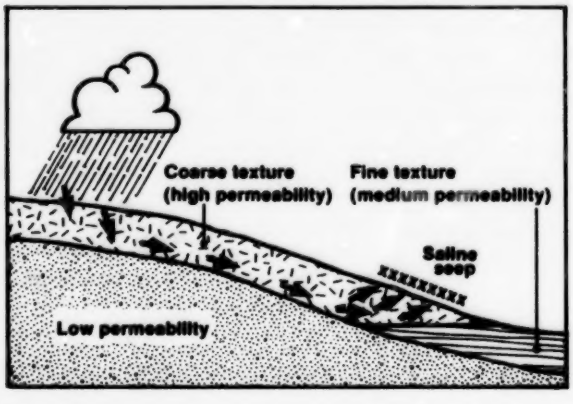

Figure 3. Texture change saline seep.

3. Aquifer outcrop saline seep - These saline seeps result from the outcropping at or near the soil surface of a permeable waterbearing layer, such as a coal seam, or a sandstone or fractured bedrock layer (Figure 4). These saline seeps sometimes occur as a chain, in a straight line and for several kilometres. The associated groundwater flow systems are generally intermediate in nature, meaning the recharge area is a few kilometres from the discharge area and covers a few sections.

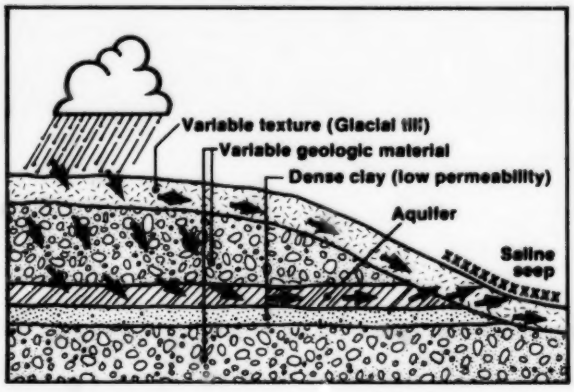

Figure 4. Aquifer outcrop saline seep (Brown et.al., 1983).

4. Hydrostatic pressure seep (Brown et.al., 1983) - Water in a hydrostatic pressure seep rises to the surface from either a pressurized bedrock or overburden aquifer (Figure 5). An aquifer is a permeable water bearing layer, confined above and below by a less permeable zone. The elevation difference between the upslope recharge area and the down-slope aquifer location pressurizes the water. Alongside hydrostatic pressure seeps, springs, soapholes and flowing wells are often found. The groundwater flow system generally is of an intermediate or regional nature.

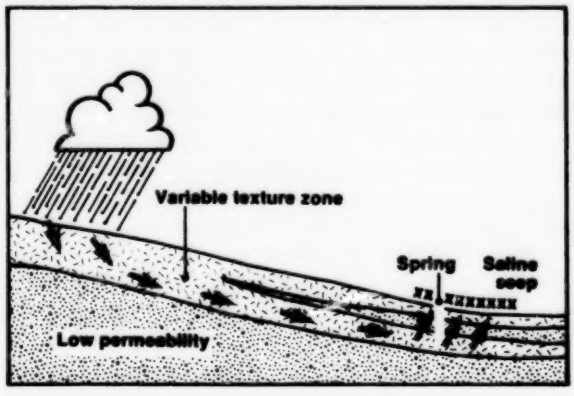

Figure 5. Hydrostatic pressure seep (Brown et.al., 1983).

Figure 6. Bathtub ring seep.

5. Bathtub ring seep (L. Henry, personal communication) - The seep is a narrow ring of salt immediately adjacent to the standing water in the slough (Figure 6). The recharge area is the slough water. It flows laterally into the soil, building a high water table at its edge from which water moves to the surface by capillary action. These saline seeps are prominent in central Alberta.

6. Depression bottom seep - These seeps result from a water table buildup in a depressional or flat area, generally on top of shallow bedrock. These seeps occur in valley bottoms, slough bottoms and eroded coulee heads. For example, most coulees in southern Alberta, such as Chin and Verdigris coulees, are salinized.

Sources of salt and water

Saline seepage is a twofold problem, one of salt and one of water. The small quantities of evenly distributed salt in the soil are no problem until they are concentrated by the groundwater in the discharge area. The main culprit of saline seepage is the water which exceeds the amount the root zone can hold. The water deep percolates beyond the root zone, increases the flow of groundwater, raises the water table and causes salt to accumulate on the surface. The occurrence of excess water seems inconsistent with the common shortage of plant available water on dryland. Both observations are correct, but apply to different soil depths and to different years. Most years, with average or below average precipitation, there is not enough moisture to fill the root zone and to guarantee the crop adequate moisture. On the other hand, ponded water and summerfallowing will fill the root zone in certain spots and fields each year, while very high annual precipitation might do this on **all** of the land once every decade. These local and regional incidents together over the last 90 years have caused enough deep percolation to bring about the present dryland saline seep problem.

Salt Source in Alberta

Bedrock and surficial material contain inherent reduced sulfur, ammonia, and organic compounds. Recent research has shown that the salts in Alberta soils are derived from the oxidation of these materials in the upper, weathered glacial till (Hendry, 1984). The sulfate and nitrate contents are many times higher in the upper glacial till as compared to the unweathered bottom portion of the surficial material. These salts rarely become a problem in the location where they are formed. However, they are transported by groundwater to the discharge areas and concentrated there on the surface by evaporation.

Excess water in recharge areas

Saline soils existed before settlement. However, practices associated with man, such as summerfallowing, have accelerated the saline seep process by increasing the amount of water that percolates beyond the root zone. This raises the water table and in the seep areas brings dissolved salts to the soil surface, where they are deposited as the water evaporates. Thus, the principal cause of dryland saline seepage is excess water. Some of the sources of excess water merit further discussion.

Water and snow accumulation - Any accumulation of water and snow may aggravate the saline seep problem. Natural ponds, roadways, railways, borrow pits, snow fences, shelterbelts, buildings, tall weeds and fence lines can trap water and snow. A study in 1976 by Canada Agriculture at Lethbridge showed that a 1100 m long shelterbelt trapped the equivalent of 10,610 m^3 of water. Following snow melt most of this water filtered into the soil near the drift. During the unusually wet 1975 spring in northwestern Montana, all depressions there were filled with runoff. As a result, the water table in the region rose 90 to 100 cm.

Summerfallow - In a summerfallow field the root zone is often filled with water, and any excess water moves down and out of the root zone to raise water

Table 2. **Amount of precipitation stored and lost in 150 cm of topsoil under summerfallow, Lethbridge (Anderson)**

	Harvest to spring	Fallow season	Fall to spring	Total
Precip.	18.3 cm	18.0 cm	16.5 cm	52.8 cm
Stored	8.6 cm	1.5 cm	3.0 cm	13.1 cm
Lost	53%	91%	81%	75%

tables and cause saline seeps. Research has shown that from the 52.8 cm (20.6 in.) of precipitation that falls in the Lethbridge region on an average during the 21 months of fallow period, 75 per cent (39.7 cm) is lost by runoff, evaporation and deep percolation (Table 2).

Sandy Soil - The average Lethbridge overwinter precipitation of 18.3 cm will more than fill a sandy root zone 1.5 m deep, because sandy soils can only store 1 cm of available water per 10 cm of soil (Figure 7). Consequently deep percolation might occur in most sandy soils during the first spring of the fallow period, and in all sandy soils during the spring following a 21 month fallow period. Similarly, deep percolation might occur some years even in clay loam soils during the spring following a 21 month fallow period.

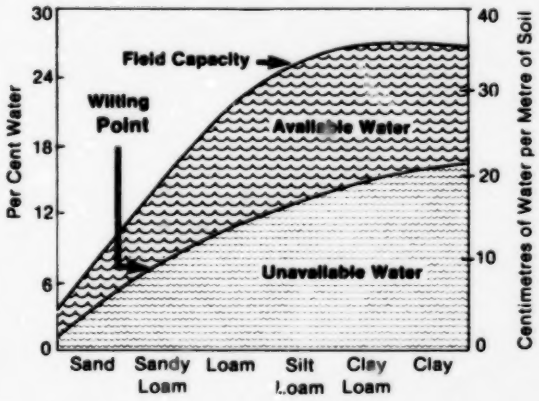

Figure 7. Water holding capacities of various soils.

High precipitation periods - During periods of high annual and seasonal precipitation, water tables show dramatic rises, which result in an increase in saline seeps. Deep percolation occurs, in general, during May and June which are the months of peak precipitation. During a series of wet years, the water table becomes progressively higher each year. Water tables on the prairies rise rapidly to maximum levels in the spring after the frost has left the soil, or after major rains. When the water table is within about 180 cm of the surface in a clay loam soil, capillary action lifts the water to the surface. Surface soil salinity is generally most severe in early spring when the water table is high, especially during a spring following a wet year. Water tables drop over the summer and reach their lowest level in late fall and winter.

Irrigation canal seepage - Dryland and irrigation land often exist side by side. Seepage from the irrigation supply canals causes a considerable amount of salinization on both dryland and irrigated land.

Subsoil moisture - Below the often powder-dry root zone, an abundance of moisture is present in the subsoil at all locations in the prairie landscape. The moisture content of the subsoil varies from moist to very moist, and is in some places and at certain times even saturated. A recent survey showed 74.5 cm more moisture in a 6 metre profile of a Dark Brown soil that was cultivated and summerfallowed compared to an adjacent native grass field (Table 3).

Table 3. **Moisture status of cultivated and non cultivated Dark Brown soil (Christie, Graveland and Palmer, 1985).**

Depth (m)	Cultivated %	Noncultivated %	Difference (cm)
0 - 1.2	24.3	12.5	21.3
1.2 - 2.4	23.2	10.8	22.2
2.4 - 3.6	19.6	11.7	14.4
3.6 - 4.8	16.4	11.5	8.9
4.8 - 6.0	16.2	12.0	7.7
	19.9	11.7	74.5

Hydrostatic water - This water, either of geologic or recent origin is trapped in gravel and sand layers, in coal seams, sandstone layers and in fractured bedrock. The aquifers are sometimes pressurized. The result on the surface is a hydrostatic pressure seep, a spring, a soaphole or a flowing well.

Dryland salinity investigation service

Saline seeps vary in soil and groundwater conditions from site to site, and so do the controls. Moreover, controls are generally costly and risky. It is, therefore, recommended that an investigation be carried out on every saline seep.

A soil and groundwater investigation service of dryland saline seeps and their recharge areas is offered by Alberta Agriculture and Prairie Farm Rehabilitation Administration (PFRA). The main purpose of an investigation is to locate dominant recharge areas and recommend control measures to farmers. Application for the service can be made with the local district agriculturist for a fee of $100 per affected quarter section. Applications are ranked as to priority and divided by regional technical coordinating or soil management committees.

The investigation consists of 4 steps:

Collecting existing information - Aerial 1:10 000 scale photographs, hydrogeological maps, and surface and bedrock geology and topography maps are collected. Soil and chemical data are obtained from water, gas and oil well records kept by the Groundwater

Resources Information Service, Alberta Environment, Edmonton.

Field inspection - During field inspections the farmer is asked the age, rate and direction of growth of the saline seep and the cropping practices used on the upslope area. The information might identify the type of saline seep and the possible location of the recharge area. Using a soil moisture probe some recharge areas are located in early spring, wherever the probe can be pushed by hand over 1 metre into the soil. Electromagnetic conductivity meters (EM31 and EM38) are used to map the relative soil salinity of a field, (Figure 8). The salinity measured in the field is mapped to aid decision making on where to drill, and to minimize the amount of drilling required.

Figure 8. Electromagnetic conductivity meters EM-31.

Drilling - Holes are drilled, topography is surveyed, and water table wells and piezometers are installed to determine the type of soil, the elevation of the ground surface, the depth to bedrock, the water table levels, and the hydrostatic pressure. Drilling is carried out with auger-type drilling units (Figure 9). These units can be outfitted with air compressers to drill in hard bedrock. The drilled holes are carefully logged for texture, geologic material, wetness, firmness, color, etc. Water table observation wells or piezometers are then installed.

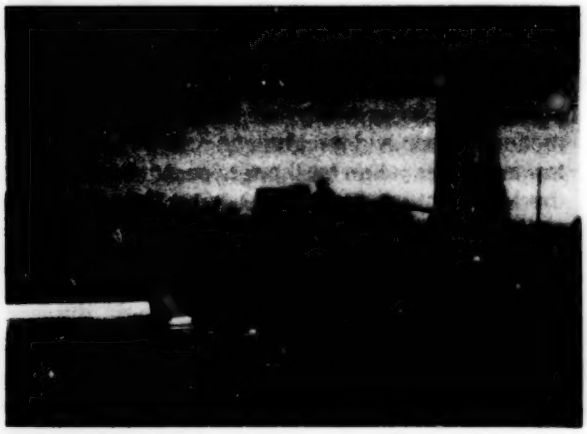

Figure 9. Auger-type drilling unit.

Piezometers are placed in nests of 2 or more at different depths. Piezometers indicate the pressure of the water in an aquifer by the height the water is pushed up in the pipe, and sometimes even above ground surface. Piezometers are pipes outfitted with a screen on the very bottom (Figure 10) which is in contact with an aquifer. A sand pack is placed around the screen portion and a watertight bentonite (driller's mud) plug is installed above the sandpack. Piezometers generally require developing in order to start the groundwater flowing in the pipe. The developing is done by surging water through the piezometer and the accompanying screen.

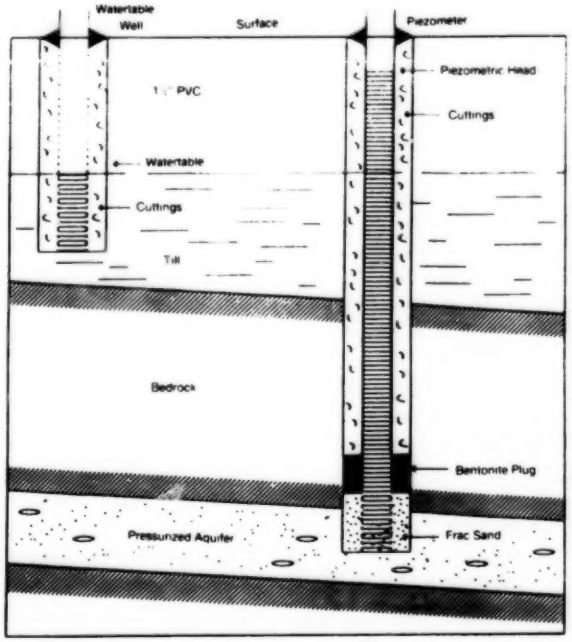

Figure 10. Water table well and piezometer construction.

Drilling is expensive, and therefore each drilling site must be carefully chosen to reveal one or more of the following:

- location and extent of shallow water table areas
- presence of saturated sand and gravel layers in the saline seep and in the drainage courses leading to the saline seep
- water table level gradients upslope and across the slope
- the presence and the hydrostatic pressure of shallow aquifers beneath or outcropping above the saline seep

- presence of upslope areas that have shallow bedrock or sandy surficial materials
- presence of finer textured material immediately downslope of the saline seep, causing a blockage to a shallow lateral groundwater flow.

Farmers are encouraged to observe the drilling operation.

Monitoring - Water table well levels usually become stabilized within 48 hours after installation, while piezometers may require a few days to months. Water table well and piezometer levels are monitored, especially during the spring. To read shallow water table wells and piezometers, a graduated 5 mm diameter plastic, semi-rigid hose is used. While blowing through the hose, air bubbles can be heard when the water table is reached (Figure 11). Monitoring by the farmer is encouraged. Monitoring should continue for many years in order to determine the effectiveness and accuracy of the recommended controls, and the need for refinement of the recommendations. Monitoring should be continued by the farmer even after reclamation is achieved and normal farm practices resumed.

Figure 11. Monitoring water table wells.

Control of dryland saline seepage

Over the years, a number of dryland salinity controls have proven to be successful. Because of the distinctiveness of each saline area and its recharge area, a different control or combination of controls is required for each site. Recommended controls are the following:

- Controls applied to recharge area
  - surface water drainage
  - high moisture use crops
  - recropping
- Controls applied to discharge area
  - subsurface drainage

Controls applied in the recharge area prevent dryland salinity and help to reclaim land showing signs of salinity. Preventing the accumulation and deep percolation of excess moisture in the recharge area is the preferred measure because it controls the salinization process at its point of origin, before it becomes a problem. Each of the controls merits further discussion.

Surface water drainage - Surface water drainage of intermittent natural and man-made ponds in the recharge area is an effective, important and often inexpensive method of control. An open trench or a buried pipe is used. The inlet of the buried pipe is about half a metre underground and connected to the surface by a gravel pack or upright standing pipe. Draining ponded water at this point is advantageous. Besides preventing deep percolation, the water is relatively salt free, and can be used as a water supply for other purposes. Because these ponds often occur in upland positions, there is a greater choice of outlets.

High moisture use crops - Deep-rooted perennials, such as forages and especially alfalfa, use more water per metre depth of soil than cereal crops and have a longer growing season. Moreover, these forage crops extract moisture from a greater depth than annual crops (Figure 12). Deep-rooted perennials use the current precipitation and prevent buildup of excess soil moisture. They lower the water table, dry out the subsoil and restore the capability of the soil to store moisture again (Figure 13). In addition, forages increase the organic matter content of a soil, improve its structure and reduce its erodibility by wind and water. Legumes, through nitrogen fixation, also increase the fertility of the soil.

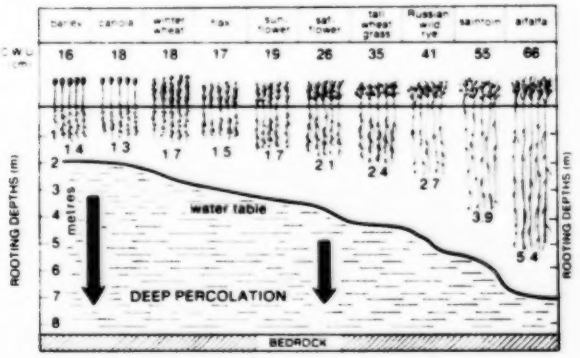

Figure 12. Cumulative water use and rooting depth during a four year period (Brown, 1971-79, USDA, Montana).

Deep-rooted forages should be planted on all dominant recharge areas identified by the soil and groundwater investigation. Generally these areas are about three times the size of the saline seep. A very common dominant recharge area is the high water

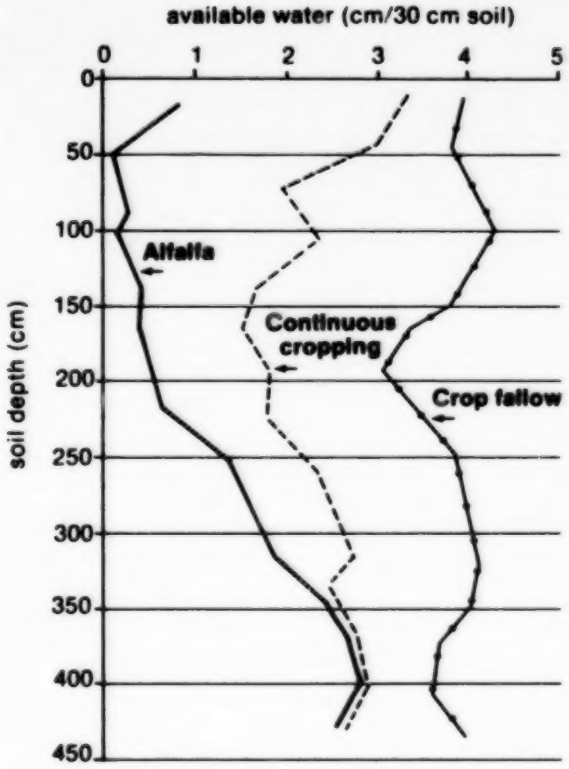

Figure 13. Available soil water under various crop systems, fall 1978 (Brown, USDA, Montana).

table area immediately adjacent and upslope of the saline seep. It might take 5 to 10 years of growing alfalfa to lower the water table in the saline seep and dry it up. The recharge area could subsequently be broken and cropped for a few years. However, the water table levels should be monitored regularly, because by using cereal crops in dominant recharge areas the water table in the saline seep could rise again. Consequently, a long-term, ongoing rotation is needed which includes several years of alfalfa each time.

Establishing forages requires the utmost care. Approximately 80 kg P_2O_5 per hectare should be deep banded prior to seeding alfalfa. Use a soil fertility analysis to provide exact recommendations. Alfalfa seed must be inoculated. The seedbed should be firm and seeding depth should be about 2 cm. The proper time for planting alfalfa is early May when the spring rains start, or the beginning of June when the soil warms up. Nurse crops should be planted at half the normal rate. The greater the area planted to forage the quicker the reclamation.

At the same time as the upslope recharge area is planted to forage, the saline seep itself should be seeded to a salt tolerant crop, preferably a grass, because many grasses are quite salt tolerant (Table 4). Plants are most affected by salinity in the early stages of growth, from germination to the four leaf stage. Saline seeps are often planted to forages in the fall when they are dry and accessible. Seeding rates for

***Table 4.* Salt tolerance of various types of crops.**

Tolerance	EC* (dS/cm)	Crops	Forages	Vegetables
			Altai wild rye grass	
	16		Tall wheat grass	
High			Slender wheat grass	
			Russian wild rye grass	
	8	6-row barley		
		Sunflower	Sweet-clover	
		2-row barley	Alfalfa	
		Oats		
		Fall rye		
		Winter wheat		Garden beets
		Spring wheat	Brome grass	
		Yellow mustard		Asparagus
Medium Moderate		Oats	Crested wheat grass	
			Intermediate wheat grass	Spinach
		Canola	Meadow fescue	
		Flax	Reed canary grass	
	4	Corn		
			Timothy	Sweet corn
			White dutch clover	
Low			Red top	Potatoes
		Peas	Alsike	Carrots
	0	Field beans	Red clover	Onions, Cabbage, Peas

** Electrical Conductivity*

saline seeps, especially when planted in the fall, are usually double those of nonsaline areas.

The following are recommended salt tolerant forage mixtures:

In nonflooded saline areas:

- 3 kg/ha Sawki or Mayak Russian wild rye grass, plus
- 2 kg/ha Summit or Nordan crested wheat grass, plus
- 3 kg/ha Altai wild rye grass, plus
- 2 kg/ha Beaver alfalfa

In saline areas subject to 2 to 5 weeks of spring flooding:

- 3 kg/ha Frontier or Castor reed canary grass, plus
- 4 kg/ha Carlton brome grass, plus
- 3 kg/ha Orbit tall wheat grass, plus
- 3 kg/ha Primar or Revenue slender wheat grass

Undrained saline areas should not be left bare for an extended period. Even weeds, such as Kochia, are preferable to a bare soil. Like grasses, Kochia will lower the water table and reduce salinization. Kochia, harvested at the midbloom stage, yields a high quality forage. Care should be exercised in feeding livestock crops from saline seeps because high nitrate levels are common.

Recropping

The widespread use of the two-year crop-fallow rotation on the prairies has contributed significantly to the saline seep problem. Therefore recropping is recommended for the dominant recharge areas where bedrock is too shallow for forages to be effective.

As research done in Montana has shown, continuous cropping results in significantly lower amounts of soil moisture than a two-year crop-fallow rotation (Figure 13). Continuous cropping was able to halt the rise in the water table. A 1978 economic study by Canada Agriculture, Lethbridge, showed that with average crop yields, continuous cropping provided the highest net return in the Black soil zone. In the Dark Brown soil zone, when grain prices were high, continuous cropping was most profitable; but when grain prices were low, the two-year crop-fallow system was most economical. When grain prices were average, two-year, three-year and continuous cropping rotations had similar returns. Thus, if salinity were a problem, a farmer could continuously crop with only a minor change in net income.

When recropping is practised, several factors should be considered:

Spring soil moisture - A minimum of 16 to 22 cm (6-9 in.) of available water from stored soil moisture and rainfall is required to successfully recrop. Stored water in the root zone must supply at least 7.5 to 10 cm

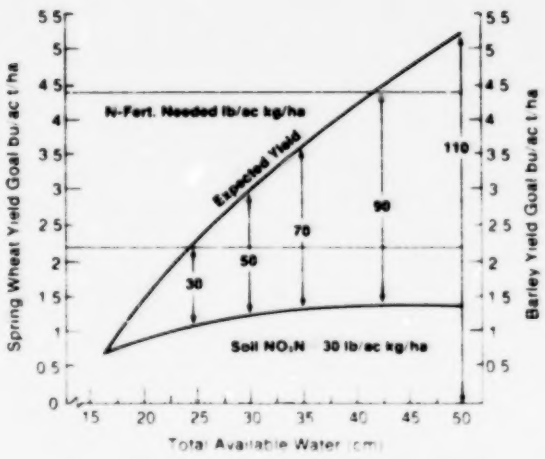

Figure 14. Effect of spring plant available water and fertilizers on crop yields (Black et al. 1979. USDA, N. Dak).

(3 to 4 in.) of this amount (Figure 14). Recropping only in those years when spring soil moisture is adequate (over 12 cm plant available water) is called "flex-cropping".

Soil moisture content can be measured with the Brown probe (Figure 15). The depth that the probe can be pushed by hand in the soil indicates the depth of wet soil. Recropping is only recommended for a clay loam soil and a sandy soil when they are wet to a depth of at least 70 and 150 cm respectively.

Figure 15. "Brown" soil moisture probe.

Snow management - While soils may have an excessive amount of water that has collected over the years below the root zone, causing saline seepage downslope, the amount of moisture present in the root zone itself may be inadequate for recropping. To supplement spring soil moisture, stubble is used to trap and evenly distribute snow over the field. Research on zero tillage and other snow management practices by Agriculture Canada has shown that standing stubble increases spring soil moisture and subsequent crop yields. The standing stubble also protects the soil from drifting and the crops from drying out. Stubble barriers and alternate stubble heights trap even more snow (Table 5). Stubble barriers are obtained by attaching straw deflectors to headers. The amount of extra water trapped by stubble bariers in comparison to bare soil at Swift Current ranged from 0.2 to 6.2 cm. Inside the Chinook belt, gains would be approximately half as much, because of the high rate of sublimation. Water gains from snow trapping approximate those of an extra 12 months of fallow.

Figure 16. Stubble barriers trapping snow.

***Table 5.* Water gains from snow management through various cultural practices in comparison to bare soil.**

	Water gains (cm)
At Swift Current	
- Stubble barriers (53 cm tall)	3.0 - 6.2
- Alternate stubble heights (32 & 15 cm tall)	0.2 - 4.7
At Lethbridge	
- Zero-tillage	2.8
- Chemicals (plus one blading in first fall)	1.2

Fertility - Recropping requires more fertilizer, especially nitrogen, to obtain good yields (Figure 14). Available nitrogen is normally built up during the fallow year as organic matter breaks down. This accumulation of nitrogen does not occur when using the recropping system. Moreover, with increased amounts of plant-available water, more fertilizer is required in order to obtain optimum yields. To determine fertilizer requirements, soil fertility and soil moisture tests would be required regularly.

Alternate crops - Alternate crops of various kinds are being used today instead of spring cereals. Most prominent of these is winter wheat, which, with its deeper (150 cm) rooting system and early spring growth, uses more moisture, and this moisture comes from deeper in the soil. Winter wheat is often planted in standing stubble, protecting it and the soil from the desiccating wind, while collecting extra amounts of snow in the winter. Generally, weeds are less of a problem in winter wheat, while insect problems are about the same.

Other promising crops which can be used in rotations are safflower (Figure 17), sunflower, sweet-clover, and others. Safflower and sunflower both have taproots, and both use more moisture than spring cereals and from deeper down (Figure 12). They are also cash crops, marketed outside the Canadian Wheat Board. Sweet-clover, a biennial, if plowed down in the second year improves the soil by adding nitrogen and organic matter.

Figure 17. Safflower field.

Subsurface drainage of saline seeps

The purpose of subsurface drainage is to remove water, keep water table levels below the critical portion of the capillary fringe, and desalinize the root zone of the saline seep. These objectives are difficult to attain because Alberta soils usually have a low permeability, for example 0.25 cm/hr, and the warm dry climate causes much capillary rise while providing little water for downward salt leaching in dryland. Nevertheless,

with proper investigation, design, installation and management, subsurface drainage can be used to reclaim saline seeps.

A proper investigation of the saline seep should include hydraulic conductivity measurements and topographical, soil and water table level surveys. Water table wells are an aid to the farmer in evaluating the severity of the problem. The most opportune time for making hydraulic conductivity measurements by the augerhole method is in the spring when water tables are high.

For dryland subsurface drainage, a grid-relief system is generally used. The grid system has several parallel lines at prescribed spacings. On southern Alberta dryland, the subsurface drainage systems must be designed to maintain water table levels deeper than 180 cm below the surface. Otherwise, a net annual upward movement of water and salt could still result. For central and northern Alberta, the critical water table depth might be shallower. A licence is required from Alberta Environment for any drainage project which diverts water onto another quarter section of land. Licensing prevents both the unwanted diversion of water and the discharge of large quantities of highly saline drainage water into streams and reservoirs.

Generally, perforated corrugated plastic tubing 100 mm (4 in.) in diameter is used for farmland drainage. Silty and flowing soils require that a filter be wrapped around the tubing and that the minimum permissible grade be increased from 0.1 per cent to 0.2 per cent. Tubing can be installed with a plow or chain trencher (Figure 18) outfitted with a laser plane depth guidance system.

Careful installation of the pipe should result in a minimum loss of soil permeability around the tile. To attain this the following practices are suggested:

- Install during the fall or late summer, when the water table is low and the soil is dry. Use trenchers in dry, hard, and layered soils and plows in wet soils.
- Backfill the trench immediately and completely when a trencher has been used.
- Pre-rip hard and frozen soils. This eliminates a considerable amount of compaction by the shear.

Figure 18. Drain trencher with laser grade control equipment.

Proper post-construction management of the drained site afterwards will aid in the success of the venture. Average amounts of precipitation are usually not adequate for leaching salts on dry land. To obtain leaching water for a subsurface drained saline-seep site:

- fallow the site
- trap snow on it
- divert and accumulate runoff onto the site.

These recommendations are the opposite to those for an undrained site, and should only be continued for a few years until the site is desalinized.

Chemical amendments

Chemical amendments, such as gypsum, have been tried experimentally to reclaim saline soils. The calcium of the calcium sulfate (gypsum) replaces the sodium on the soil complex and thus reduces the sodic condition of the soil. Because of the low solubility of gypsum, its success has been very limited, especially in soils with an electrical conductivity over 2 dS/m. Sulfur is often mentioned, but its use is restricted to soils with high lime content. However, none of the saline seep soils in Alberta have this.

There are no chemical amendments that will "neutralize" the salts present in the soil. The salts that cause the problem are neutral. Heavy applications of manure at 35 to 45 tonnes per hectare have improved crop establishment and crop yields on saline soil to some extent. Manure application increases the organic matter content, water-holding capacity and aeration of the soil. It also adds nutrients and improves the structure and tilth of the soil.

Summary

Dryland saline seeps are growing in size and severity in Alberta. They are caused by excess moisture percolating deeply into the soil, increasing groundwater flow, and subsequently depositing salts in the discharge area. Summerfallow, ponds, reservoirs, borrow pits and snowfences contribute to recharge and subsequent salinization.

To determine the cause of the saline seep and locate the "dominant" recharge areas, a soil and groundwater investigation should be carried out. Monitoring water table levels is an integral part of the

investigation.

To control saline seeps the following practices have proven successful:

- Drain surface accumulations of water.
- Reduce summerfallow by adopting longer rotations.
- Include deep rooted crops with a high moisture requirement, such as alfalfa, in the rotation. Plant these around and above the affected areas to dry out the subsoil and quickly lower the water table.
- Eliminate barriers that trap large amounts of snow and water.
- Install subsurface drain tiles in coarse and medium textured saline seeps.
- Eliminate seepage from irrigation canals.
- Plant salt-tolerant crops in the affected areas.